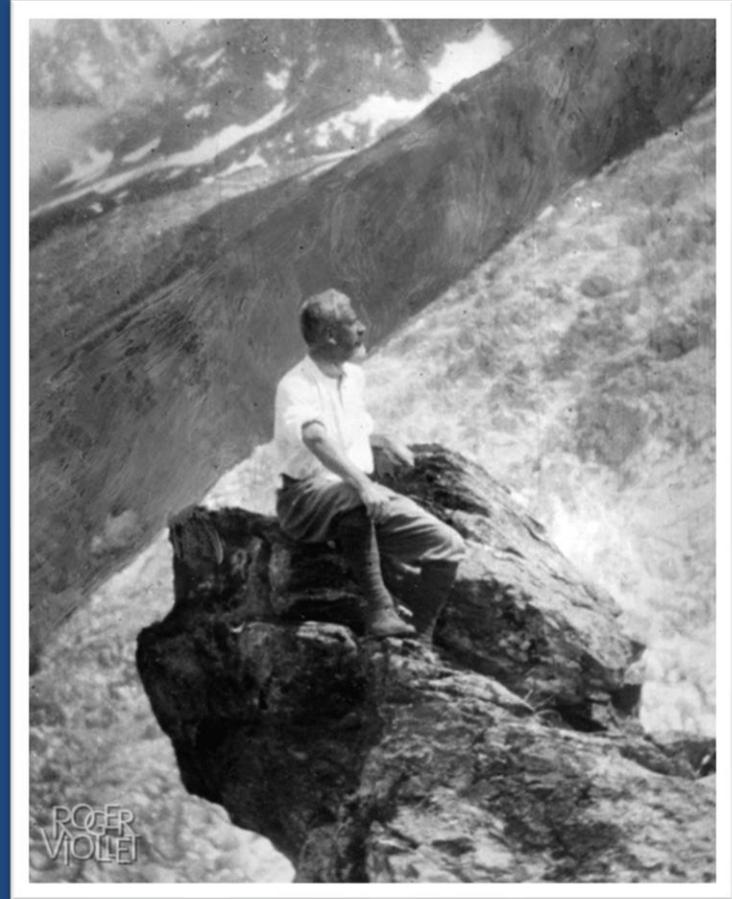# The legacy of
Charles-Édouard Guillaume
Swiss perspective

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Guillaume and Switzerland

- Charles-Édouard Guillaume was born
  in Fleurier in Val de Travers
  on 15 February 1861.
  The city of Fleurier has two Nobel laureates!

- From a watchmaking family, he focused part
  of his research on precision watchmaking and
  collaborated all his life with the watchmaking
  circles in his birth region.

- Even after 53 years devoted to the
  International Bureau of Weights and
  Measures, Charles-Édouard Guillaume
  remained deeply attached to Switzerland.

Guillaume's family home in Fleurier
© Fondation C.-E. Guillaume, Fleurier

Guillaume and Switzerland

– In Switzerland, the memory of Charles-Édouard Guillaume, who became famous for his Nobel prize, is strongly associated with his work on precision horology.
On the opening of one of the conferences he gave at La Chaux de Fonds, he declared:

> *« Quand on parcourt les montagnes neuchâteloises, on est frappé par l'importance de l'horlogerie. » [When you walk in the mountains of the Neuchâtel region you are stunned by the importance of horology.]*

– In 1815, Charles-Frédéric Guillaume, Charles-Édouard Guillaume's grandfather, sought refuge in England where he married a descendant of Revocation refugees who came from the Neuchâtel region.

– They started a family and had three boys and established a horology activity. Charles-Édouard Guillaume's father, who grew up in London before going back to Switzerland, became in turn a horologist. He is also highly educated and passed on to Charles-Édouard the taste for knowledge and horology.

Precision horology

– The discovery of invar was an opportunity to return to the family tradition.

> *« L'existence de l'erreur secondaire des montres (…) m'avait été enseignée par mon père, et j'avais souvent pensé à la joie immense que j'éprouverais, si je pouvais lui en apporter la solution. »*
> *[The existence of the secondary error of watches (…) was taught to me by my father and I often thought about the immense joy which I would feel if I could find a solution.]*

– Guillaume's work on nickel-iron alloys was also an opportunity to solve the problem of the compensation of the temperature effects on the rate of watches.

*© Musée international de l'horlogerie (MIH)*
(La Chaux de Fonds)

Invar rod pendulum

– Guillaume developed a compensated invar rod pendulum which set him on the road to the first compensating spring made of an iron-nickel alloy with 28 % of nickel (called a Paul Perret spring).

– By replacing the steel rod of the pendulum by an invar rod, compensation can be realized with a bronze mirror lens.

© MIH (La Chaux de Fonds, Switzerland)

Invar springs

– From the publication of the first results on invar, the horologist Paul Perret asked Guillaume for an invar sample. Assisted by the engineer Marc Thury (who suggested the name 'invar'), Perret discovered that invar had a positive coefficient of thermal expansion. It marked the beginning of an intense collaboration between Paul Perret and Charles-Édouard Guillaume.

– Since the summer of 1897, using alloys containing 28 % and 45 % of nickel for which the coefficient of thermal expansion is practically zero, they developed a first compensating spring. In the following years, more than **50 millions** of these springs were produced and used in ordinary watches, since this spring only allows for an incomplete compensation.

Archives MIH
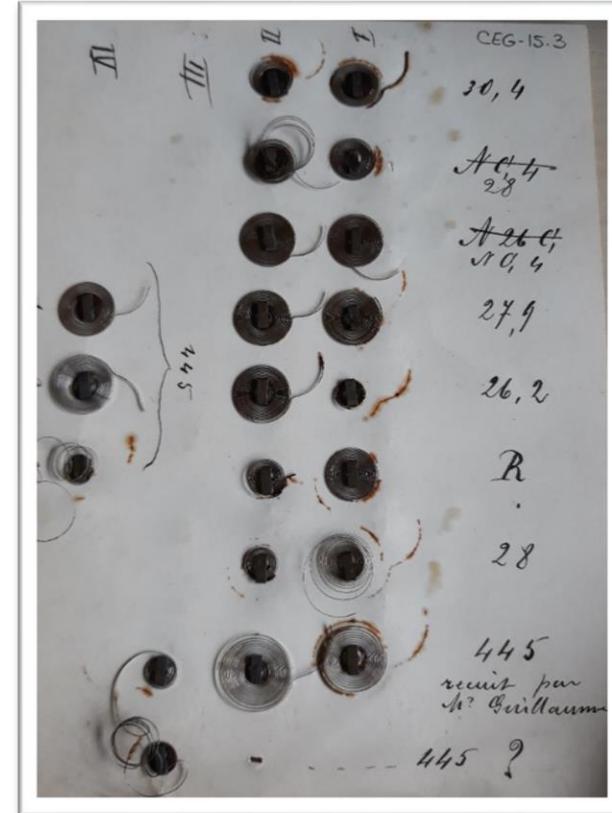
A solution to the secondary error of watches

– The secondary error of watches is linked to a lack of proportionality between rate and temperature.

– Charles-Édouard Guillaume felt that the solution was in the use of nickel steel. He explained his idea as follows:

> *« J'étudiai le mémoire qu'Yvon Villarceau a publié dans le tome VII des Annales de l'Observatoire de Paris. Un soir du printemps 1899, la solution complète émergea tout à coup, fondée sur l'existence d'un coefficient quadratique négatif dans l'équation de dilatabilité d'une catégorie d'aciers au nickel. » [I was studying the essay published by Yvon Villarceau in Volume VI of the Annals of the Paris Observatory. One evening of the 1899 spring, I suddenly had the full solution, based on the existence of a negative quadratic coefficient in the thermal expansion equation of a certain category of nickel steels.]*


© MIH

– The horologists Paul-D. Nardin in Locle and Paul Ditisheim in La Chaux de Fonds carried out tests using the new balance that confirmed Guillaume's theory. **The secondary error was completely eliminated**. The first official results were presented at the Neuchâtel Observatory in front of Adolphe Hirsch.

A solution to the secondary error of watches
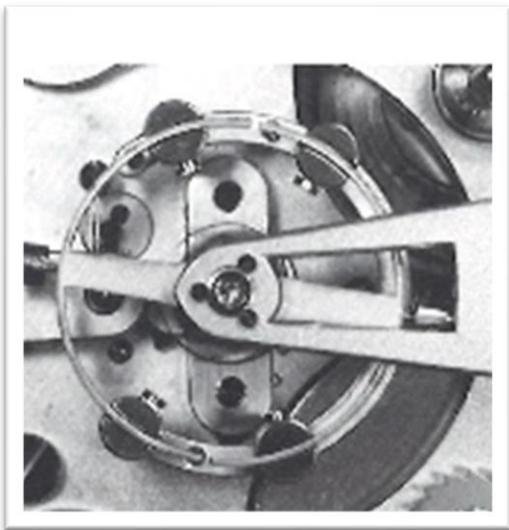
The integral balance called the Guillaume balance, which eliminates errors due to thermal variations, is used for high-grade watches.
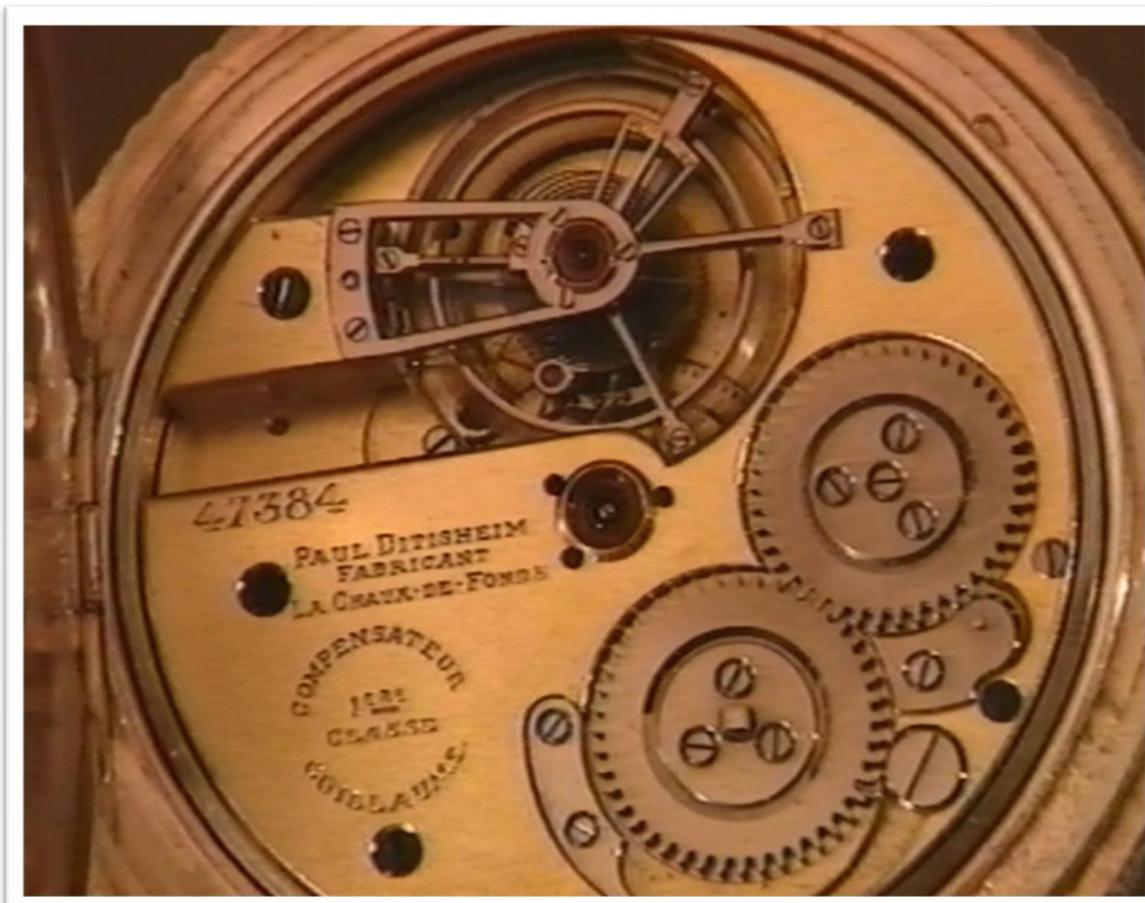
Elinvar

– In 1912, Guillaume had the idea to add to these alloys large quantities of metals such manganese or chromium. He thought it would allow him to reach full compensation, including for chronometers, by the association via a monometallic balance of a spring made of a new type of alloy:
elinvar (invariable elasticity).

– It will be eight year before the development of this new spring: **the results were announced in 1920 in a communication to the Academy of Sciences**.


*The first monometallic balance with an elinvar spring - Zenith chronographe, 1916.*

Culmination of 20 years or research

– The development of this new spring was welcomed by the horology industry from the Neuchâtel region as a true revolution.

– This milestone marked the end of Guillaume's research in horology.

– With invar and elinvar, Charles-Édouard Guillaume brought major progress to horology: thanks to the Guillaume balance, the rate discrepancies of marine and on-board chronometers are reduced to one tenth of a second. The invar pendulum that controls the beatings of astronomical clocks provides an accuracy in the order of one hundredth of a second.
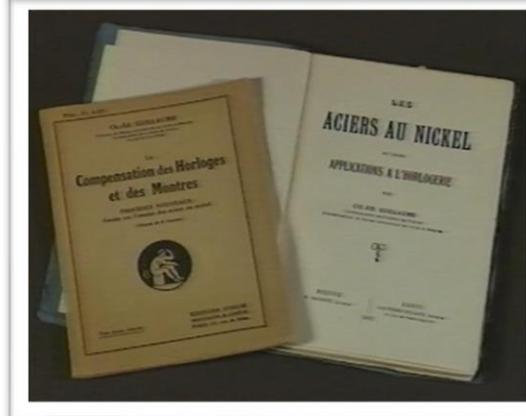
Consecration

– The industrial application of Guillaume's discoveries to horology and chronometry was entrusted to the Société des Fabriques des Spiraux Réunies.

– In 1920, Guillaume's work on iron-nickel alloys was recognized with award of the Nobel prize in Physics.
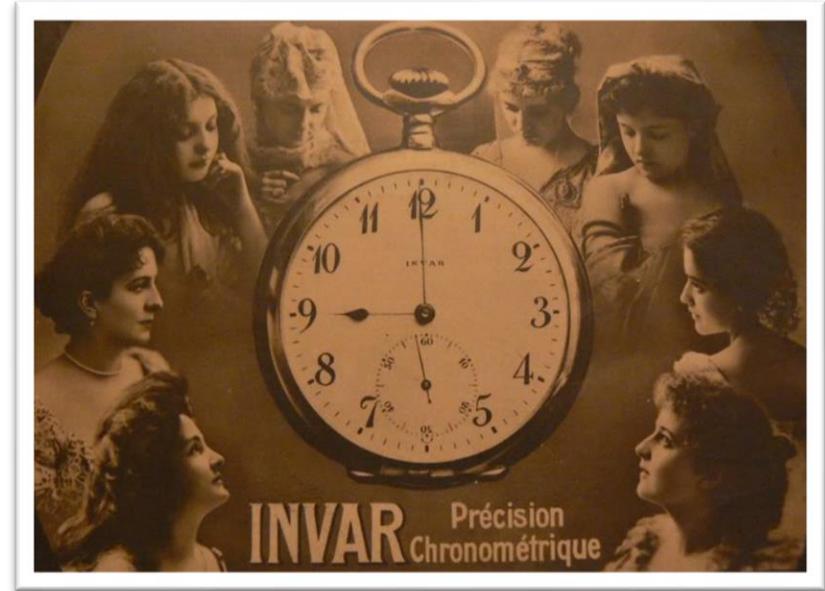
Posterity

– In 1927, 100 million watches were made with elinvar springs.

– In 1958, Ernest Dubois, director of the Société des Spiraux réunis recalled Charles-Édouard Guillaume's work during a ceremony by saying:

« Tous les chercheurs qui lui ont succédé sont plus ou moins ses élèves. À la seule exception du spiral à structure d'acier trempé, qui se situe dans le domaine des aciers irréversibles, tous les autres spiraux compensateurs sont les descendants très directs des spiraux du Dr Guillaume. (…) La multiplicité des chercheurs qui dans tous les pays se sont efforcés de perfectionner l'élinvar prouve que la découverte de cet alliage a eu pour l'horlogerie une valeur inestimable. »

[All the researchers that succeeded to Guillaume are more or less his students. With the exception of the hardened steel spring, which is a type of irreversible steels, all other compensating springs are direct descendants of Guillaume's spring. (...) The large number of researchers from all countries that strove to perfect elinvar shows that the discovery of this alloy had a priceless value for horology.]

CHARLES-ÉDOUARD GUILLAUME
1861 – 1938
(D'après un pastel de O. Matthey)
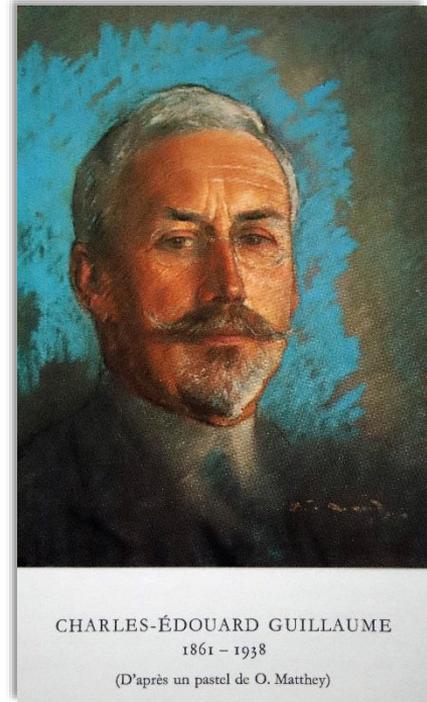
The next horology revolution

- **Silicon springs** and totally anti-magnetic mechanical movements are the solution to the dependence on magnetic fields.

- 2002: Ulysse Nardin: first watch with silicon spring
- 2003: R&D project (OMEGA, Patek Philippe and Rolex)
- 2006: First operating spiral (300 watches)
- 2008: Industrialization and introduction in the OMEGA watch collection
- 2013: First anti-magnetic watch (resisting to 1.5 Tesla)
- 2015: First Master Chronometer Certificate (issued by METAS)
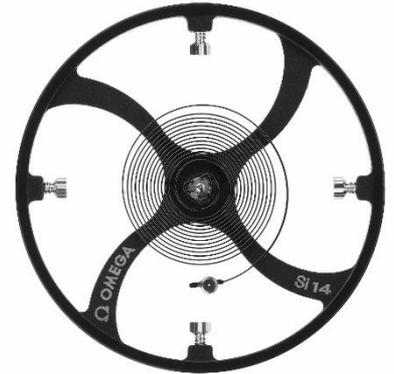
This technology revolution clearly finds its inspiring principle in Charles-Édouard Guillaume's discoveries, almost 100 years after his Nobel prize in Physics.